User's Manual for "PC-SEED"

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PC-SEED worksheet report: Peatland black spruce
Printed on 04-13-1999 Filename: SAMPLE.PCS

Seedbed Type	Recept	Area	Q1	Q2	Q3	Q4	Q5	Q6	Q7
compact Sphagnum	7.7	10.0	15.9	4.9	3.2	1.2	10.7	1.5	13.0
Sphagnum peat	33.4	7.2	2.2	13.8	8.5	1.1	10.8	2.7	6.7
Sphagnum and grass	6.9	3.5	2.7	1.1	2.0	1.3	1.0	1.0	21.7
pioneer mosses	11.4	3.2	4.7	3.2	1.7	1.4	0.9	0.9	1.0
feathermoss peat	3.4	3.8	1.8	2.3	3.1	1.1	1.0	1.0	13.8
displaced Sphagnum	20.6	2.3	0.9	1.8	15.6	0.9	2.7	0.9	0.9
deciduous litter	0.1	1.5	0.7	0.8	0.9	2.1	0.7	0.7	0.7
coniferous litter	6.4	1.7	0.8	0.9	11.8	5.1	0.8	0.8	1.5
sheared Sphagnum	42.7	1.4	1.8	0.8	0.7	0.8	0.7	0.7	0.7
displaced feathermos	3.4	1.1	0.7	2.4	0.6	0.6	0.6	0.7	0.6
rotten wood A	32.4	1.0	0.6	2.0	0.7	0.6	0.6	0.6	1.0
other	2.0	16.8	13.3	1.4	9.7	15.4	31.1	4.4	3.5
Quadrat Area:		53.5	46.0	35.5	58.6	31.5	61.7	15.9	65.1
Quadrat Stocking:		71.6	72.1	85.3	88.0	51.2	81.5	53.2	80.8

Seedbed Type	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
compact Sphagnum	30.4	6.0	1.8	2.6	24.0	1.2	1.3	8.8	2.1
Sphagnum peat	1.2	1.1	5.3	1.4	23.9	1.1	1.8	3.4	4.2
Sphagnum and grass	1.0	1.0	8.1	1.1	1.0	1.0	1.6	1.0	1.0
pioneer mosses	0.9	0.9	1.1	1.2	0.9	1.0	20.3	0.9	0.9
feathermoss peat	9.0	1.1	4.3	1.0	23.0	1.0	6.1	1.0	1.0
displaced Sphagnum	0.9	1.1	0.9	1.3	0.9	0.9	0.9	0.9	0.9
deciduous litter	0.7	0.7	0.7	0.7	0.7	0.7	1.2	0.7	0.7
coniferous litter	0.8	0.8	0.8	0.8	0.8	0.8	2.6	0.8	0.8
sheared Sphagnum	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
displaced feathermos	7.2	0.6	0.6	0.8	0.6	0.7	0.6	0.6	0.6
rotten wood A	0.6	6.3	0.6	0.6	0.6	0.6	0.6	0.6	0.6
other	36.2	6.8	17.8	26.9	1.9	42.9	11.4	53.0	8.2
Quadrat Area:	89.7	27.1	42.7	39.1	79.1	52.6	49.2	72.5	21.8
Quadrat Stocking:	65.4	70.9	70.0	52.1	88.6	47.6	68.4	64.4	60.7

Seedbed Type	Q17	Q18	Q19	Q20
compact Sphagnum	3.9	7.3	19.4	40.7
Sphagnum peat	34.1	17.9	1.2	1.6
Sphagnum and grass	3.7	12.7	1.0	5.4
pioneer mosses	11.5	7.2	0.9	2.3
feathermoss peat	1.0	1.0	1.4	1.2
displaced Sphagnum	4.4	1.0	0.9	7.8
deciduous litter	0.8	10.4	4.2	0.7
coniferous litter	1.1	0.8	0.8	0.8
sheared Sphagnum	1.1	9.6	0.7	3.8
displaced feathermos	0.6	1.2	0.6	0.6
rotten wood A	0.6	0.6	0.6	0.6
other	20.4	5.6	23.4	2.6
Quadrat Area:	83.3	75.1	55.3	68.2
Quadrat Stocking:	93.6	95.6	58.5	85.0

Figure 2. Worksheet report.

SEEDBED REPORT:
Peatland black spruce

Report Date: 04-13-1999

File: SAMPLE.PCS

	Seedbed Type	Receptivity (%)	Seedspot Stocking (%)	Average Area (%)	Alpha	Beta
1	compact Sphagnum	7.7	24.5	10.0	0.1440	1.7260
2	Sphagnum peat	33.4	73.5	7.2	0.6246	1.2454
3	Sphagnum and grass	6.9	22.2	3.5	0.1290	1.7410
4	pioneer mosses	11.4	34.3	3.2	0.2132	1.6568
5	feathermoss peat	3.4	11.5	3.8	0.0636	1.8064
6	displaced Sphagnum	20.6	54.3	2.3	0.3852	1.4848
7	deciduous litter	0.1	0.4	1.5	0.0019	1.8681
8	coniferous litter	6.4	20.7	1.7	0.1197	1.7503
9	sheared Sphagnum	42.7	82.9	1.4	0.7985	1.0715
10	displaced feathermos	3.4	11.5	1.1	0.0636	1.8064
11	rotten wood A	32.4	72.3	1.0	0.6059	1.2641
12	other	2.0	6.9	16.8	0.0374	1.8326

* Seedspot stocking values based on 8 seeds per spot with a viability of 100 %

Figure 3. Seedbed report.

image remains on the screen until all of the graph information has been sent to the printer. This can take some time, and in the meanwhile no keystrokes are accepted.

|Print|Graph|Stocking

Print a graph of stocking versus seeding rate in broadcast seeding (see Figure 4).

|Print|Graph|Stocking|1) Scale 50

Select a seeding rate scale going from 0 to 50,000 seeds per ha for the stocking graph.

|Print|Graph|Stocking|1) Scale 200

Select a seeding rate scale going from 0 to 200,000 seeds per ha for the stocking graph.

|Print|Graph|Stocking|1) Scale 500

Select a seeding rate scale going from 0 to 500,000 seeds per ha for the stocking graph.

|Print|Graph|Density

Display a graph of density versus seeding rate in broadcast seeding (see Figure 5).

|Print|Graph|Density|1) Scale 50

Select a seeding rate scale going from 0 to 50,000 seeds per ha for the density graph.

|Print|Graph|Density|1) Scale 200

Select a seeding rate scale going from 0 to 200,000 seeds per ha for the density graph.

|Print|Graph|Density|1) Scale 500

Select a seeding rate scale going from 0 to 500,000 seeds per ha for the density graph.

|Print|Graph|Seedspot

Print a graph showing the percentage of seedspots with 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 or more seedlings per spot (see Figure 6) for the current seedbed.

|Print|Graph|Frequency

Print a graph of the relative frequency distribution of seedbed area for the current seedbed.

|Print|Worksheet

Print the contents of the worksheet (see Figure 2). The worksheet report reproduces the information contained in the worksheet including the name, receptivity and average area of each seedbed type; the area of each seedbed type in each quadrat; the mean total seedbed area and the mean stocking; and the total seedbed area and the probability of stocking for each quadrat.

|Print|Worksheet|Normal

Print the worksheet in normal text mode, 80 columns wide.

|Print|Worksheet|Compressed

Print the worksheet in compressed text mode, 137 columns wide. This option is possible for printers using the Epson command set.

|Print|Title

Enter a title (up to 40 characters) to be printed at the top of graphs or reports.

|Print|Seedbed Report

Print a report summarizing the receptivity, seedspot stocking, average area, and alpha and beta values for each seedbed type (see Figure 3). Seedspot stocking is the estimated stocking if seedspots were established on each seedbed type.

|Graph

Select one of several graph options.

|Graph|Stocking

Display a graph of stocking versus seeding rate in broadcast seeding (see Figure 4). Pressing "P" while the graph is displayed will print the graph; pressing any other key will return to the worksheet.

|Graph|Stocking|1) Scale 50

Select a seeding rate scale going from 0 to 50,000 seeds per ha for the stocking graph.

|Graph|Stocking|1) Scale 200

Select a seeding rate scale going from 0 to 200,000 seeds per ha for the stocking graph.

|Graph|Stocking|1) Scale 500

Select a seeding rate scale going from 0 to 500,000 seeds per ha for the stocking graph.

|Graph|Density

Display a graph of stocking versus seeding rate in broadcast seeding (see Figure 5). Pressing "P" while the graph is displayed will print the graph; pressing any other key will return to the worksheet.

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ABSTRACT

The software "PC-SEED" has been developed to carry out computations required to help develop prescriptions for direct seeding. "PC-SEED" computes stocking and density for broadcast and spot seeding, and also performs some related computations.

This manual outlines how to install and run "PC-SEED", and describes how to use "PC-SEED" for several applications. A complete listing and explanation of all menu commands is provided.

The manual includes a 3 1/2" floppy diskette with the files necessary to run "PC-SEED". The program is written in QuickBasic, and runs on MS-DOS compatible computers.

RÉSUMÉ

Le logiciel PC-SEED a été développé pour effectuer les calculs nécessaires à l'élaboration des prescriptions d'ensemencement direct. Il calcule la proportion de surface occupée et la densité des semis en plein (ensemencement à la volée) et des semis localisés (ensemencement sur placeaux) et effectue des calculs connexes.

Le présent manuel explique comment installer et utiliser le logiciel PC-SEED et décrit ses diverses applications. Il fournit la liste complète des commandes de menu et en présente une description.

Le manuel est accompagné d'une disquette de 3 pouces contenant les fichiers nécessaires pour exécuter PC-SEED. Le programme est en QuickBasic et tourne sur des ordinateurs MS-DOS.

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INTRODUCTION

Direct seeding is a widely used forest regeneration method in Ontario, particularly for jack pine, and to a lesser extent, black spruce. Direct seeding includes broadcast seeding, row, and spot seeding. In broadcast seeding, seed is spread over the entire regeneration area, usually from seeding devices mounted on aircraft. In row seeding, seeds are applied to intermittent or continuous rows of prepared seedbed, usually by a mechanical device mounted on site preparation equipment. In spot seeding, groups of one or more seeds are placed at suitable spots throughout the regeneration area.

The objective of direct seeding is to establish a stand of the seeded species to a desired regeneration stocking and density. In broadcast seeding, probabilistic models can be used to explore the stocking that will result from various combinations of seeding rate, seed viability, seedbed amounts and seedbed receptivities (Régnière 1982, Groot 1988), but these models require a considerable amount of computation. Estimating stocking in spot seeding also requires computations involving seedbed receptivity, seed viability and number of seeds per spot.

It should be noted that probabilistic models cannot be used to predict the outcome of a particular direct seeding operation. Variability in site type, seedbed conditions, seed viability, seed application and weather all affect seedling establishment, and preclude accurate forecasts. Probabilistic models can be used, however, to help develop prescriptions for direct seeding, because they allow examination of how seeding rate, seedbed amount and seedbed receptivity influence stocking and density.

This manual describes PC-SEED, a program that carries out computations for probablistic models in direct seeding. PC-SEED is similar to older versions of popular spreadsheet programs in appearance and some functions, making it easy to learn. PC-SEED computes potential regeneration stocking and densities from user-entered seeding rates, seedbed amounts and seedbed receptivities, and displays the results in graphic form. Because complete information on seedbed distribution is not always available, an option allows seedbed areas to be generated internally. PC-SEED also computes stocking for seedspots.

This manual explains how to install and run PC-SEED, describes the worksheet, provides a brief tutorial introducing PC-SEED, describes how to use PC-SEED to perform several tasks, and gives a complete listing and explanation of all menu commands.

Computer operating systems have developed more rapidly than PC-SEED, and this software does not have the advantages of a graphical user interface and does not support a mouse.

INSTALLING AND RUNNING PC-SEED

The files required for PC-SEED are contained on the diskette included with this report (Table 1).

Table 1. PC-SEED files.

File	Description
SEED.EXE	main program
PCSEED.BAT	batch file normally used to run PC-SEED
SAMPLE.PCS	a sample PC-SEED data file
INTRO.EXE	self-displaying introductory screen
BETA.EXE	program to estimate α and β values (see Appendix 2)

A hard disk drive subdirectory (e.g., C:\PCSEED) should be created, and all of the files copied to that subdirectory. This can done through whichever operating system is most convenient. In DOS, the commands are:

mkdir c:\pcseed

copy a:*.* c:\pcseed

PC-SEED can be run from either a floppy disk drive or from the hard disk drive. Change to the drive or directory that contains the PC-SEED files and, at the DOS prompt, type:

pcseed

This method runs the batch file PCSEED.BAT. This batch file contains the DOS command **graphics**, which allows graphs created by PC-SEED to be printed. An alternate method of running PC-SEED is to first type the **graphics** command, with any parameters[1] desired, and then to type the **seed** command. This method permits control over the type of printer. Remember to type the **graphics** command before the **seed** command if using this method; otherwise graphs will not print properly, or the program may not run properly.

[1] the parameters permissible depend on the version of DOS installed on the computer. Consult your DOS manual. An example of the command is graphics laserjetii, which allows graphics to be printed to a laser printer.

THE WORKSHEET

When PC-SEED is run, a worksheet consisting of 20 rows and 10 columns appears (Figure 1). Each row represents a seedbed type, and each column provides information about the seedbed type. The first column, entitled Seedbed Type, indicates the seedbed name. The second column, entitled Recept, indicates the receptivity of the seedbed. Receptivity is the proportion of viable seeds that become established seedlings, and can vary from 0 to 100%. The third column, entitled Area, indicates the mean area of the seedbed type. The remaining columns, entitled Q1 to Q200, indicate the areas of individual quadrats. Both mean and individual quadrat areas are expressed in proportional terms, varying from 0 to 100%.

The main menu appears at the top of the screen and a quadrat summary line appears in the second line from the bottom of the screen. A help line is provided in the bottom line of the screen.

A BRIEF TUTORIAL

The best way to become familiar with PC-SEED is to start using it. Begin by entering a seedbed name (e.g., "mineral soil") in the cell under the column heading "Seedbed Type". Cell entry and cursor movement are controlled by standard keys (Table 2). Enter a receptivity value (e.g., 20, which means 20 established seedlings per 100 seeds sown) for seedbed 1 under the "Recept" column. In the default mode, values cannot be entered in the "Area" column, so the next entries must be made in the "Q1" and subsequent columns. For example, enter quadrat areas for Q1 to Q10 (e.g., 12, 24, 17, 5, 37 etc.). Only values between 0 and 100 will be accepted. These represent the percent area of the quadrat covered by this seedbed type. After each value is entered, the mean area of the seedbed is updated in the "Area" column. The total quadrat area is given in the summary line at the bottom of the screen (with only one seedbed type the total area is the same as the area for the seedbed). Note that the "Seedbed", "Recept" and "Area" columns always remain on the screen, while the quadrat columns scroll horizontally.

Table 2. Worksheet keys.

Key	Function
Enter	Enter the value into the cell.
→	Enter the value and move one cell right.
←	Enter the value and move one cell left.
↑	Enter the value and move one cell up.
↓	Enter the value and move one cell down.
Ctrl→	Move seven cells right.
Ctrl←	Move seven cells left.
Home	Move to the upper left corner of the worksheet.
Backspace	Erase the last character entered.
Del	Deletes the contents of the current cell
Esc	Return to the previous menu selection.
/	Access the main menu.
F7	Quit

File Calculate **Print** **Graph** **Setup**

	Seedbed Type	Recept	Area	Q1	Q2	Q3	Q4	Q5	Q6	Q7
								Average SAMPLE.PCS		
1	compact Sphagnum	7.7	10.0	15.9	4.9	3.2	1.2	10.7	1.5	13.0
2	Sphagnum peat	33.4	7.2	2.2	13.8	8.5	1.1	10.8	2.7	6.7
3	Sphagnum and grass	6.9	3.5	2.7	1.1	2.0	1.3	1.0	1.0	21.7
4	pioneer mosses	11.4	3.2	4.7	3.2	1.7	1.4	0.9	0.9	1.0
5	feathermoss peat	3.4	3.8	1.8	2.3	3.1	1.1	1.0	1.0	13.8
6	displaced Sphagnum	20.6	2.3	0.9	1.8	15.6	0.9	2.7	0.9	0.9
7	deciduous litter	0.1	1.5	0.7	0.8	0.9	2.1	0.7	0.7	0.7
8	coniferous litter	6.4	1.7	0.8	0.9	11.8	5.1	0.8	0.8	1.5
9	sheared Sphagnum	42.7	1.4	1.8	0.8	0.7	0.8	0.7	0.7	0.7
10	displaced feathermos	3.4	1.1	0.7	2.4	0.6	0.6	0.6	0.7	0.6
11	rotten wood A	32.4	1.0	0.6	2.0	0.7	0.6	0.6	0.6	1.0
12	other	2.0	16.8	13.3	1.4	9.7	15.4	31.1	4.4	3.5
13										
14										
15										
16										
17										
18										
19										
20										
	Area:		53.5	46.0	35.5	58.6	31.5	61.7	15.9	65.1

Enter seedbed name OR Type / to access the main menu

Figure 1. PC-SEED worksheet.

Now access the main menu by typing **/.** Select **Graph** by typing **g**, or by using the right or left arrow keys and typing **Enter**. Type **s** or the **Enter** key to select a stocking graph, and then type **1** or the **Enter** key to select the first graph scale. A graph of stocking versus seeding rate is displayed.

Congratulations! You have completed your first stocking predictions using PC-SEED.

Press the space bar to return to the worksheet. Continue experimenting with PC-SEED or conclude your session by selecting **File** and then **Exit** from the main menu.

USING PC-SEED

Examining stocking relationships in broadcast seeding

One of the main functions of PC-SEED is to examine stocking relationships in broadcast seeding. Seedbed receptivity values, seedbed areas and seeding rates are used in the calculations.

Results can be displayed in two ways. A graph of stocking versus seeding rate can be viewed by selecting **|Graph|Stocking** and then an appropriate graph scale. The graph can be printed by selecting **|Print|Graph|Stocking** and an appropriate graph scale.

A quadrat summary for stocking can be displayed along the bottom of the worksheet by selecting **|Setup|Bottom|Stocking**. These values give the probability that a quadrat will be stocked, and are based on a single seeding rate. The default rate is 100,000 viable seeds ha^{-1}, but any rate up to 500,000 seeds ha^{-1} can be chosen by selecting **|Calculate|Broadcast|Rate.** The area of the stocking unit (regeneration quadrat) can be altered by selecting **|Calculate|Broadcast|Quadrat**. The default area is 4.0 m^2, and areas from 0 to 100 m^2 can be entered. The value of stocking at the bottom of the Area column is the average for all quadrats. The value at the bottom of each Q column is the probability that the quadrat is stocked.

Within-seedbed variability (α and β values)

The variability in receptivity that occurs within a seedbed type is currently not well understood, but it has a strong effect on stocking. In a variable seedbed type, establishment is poor on some patches of the seedbed but good on other patches. In a uniform type, establishment is similar among all patches. For a given seedbed receptivity, higher within-seedbed variability leads to lower stocking.

Variability in receptivity within a type probably occurs because patches of a seedbed type may be similar in appearance, yet differ in the properties that affect establishment (e.g., moisture). Variability also occurs if the definition of the seedbed type is so broad that a number of conditions occur within it.

Groot (1988) showed that seedspot stocking on peatland seedbed types is consistently below values expected for seedbeds with uniform receptivity values, and that it is necessary to account for within-seedbed variability to obtain reasonable stocking predictions.

It is probable that within-seedbed variability is scale-dependent, with variability decreasing as average seedbed patch size increases. This supposition has not been substantiated, however.

PC-SEED uses the beta probability density function to describe within-seedbed variability. This function has two parameters,α and β, which are related to the receptivity, r, by:

$$r = \frac{\alpha}{\alpha+\beta} \times 100 \qquad [1]$$

Many combinations of α and β are possible for a single receptivity value. When α and β are small, within-seedbed variability is high; the extreme case of high variability would occur with patches of a given seedbed type being either fully receptive or completely unreceptive. Large α and β values correspond with low within-seedbed variability; the extreme case of low variability would occur with all patches of a given seedbed type having the same receptivity.

For black spruce on peatland seedbed types, Groot (1988) found that the value of α was linearly related to receptivity by:

$$\alpha = -0.0005 + 1.87 \times (\text{receptivity}/100) \qquad [2]$$

When a receptivity value is entered, this relationship (with the intercept rounded to 0) is used by PC-SEED to determine values of α, and then from [1], β.

No study of within-seedbed variability has been made for other species or other conditions, and it is possible that equation [2] is not universally applicable. However, values of α and β should be changed only if there is good cause for doing so. Data from seedspots can be used to provide local estimates of α and β (see Appendix 2).

It is possible to alter the values of α and β in two ways. Selecting **|Calculate|βeta|Parameters** permits new values of the intercept and slope to be entered for equation 2. Values of α and β can be entered directly for a single seedbed type by selecting **|Calculate**

βeta|Enter Values. This results in a new receptivity value being computed according to equation [1].

It is possible to determine what stocking would be if seedbeds were uniform by setting very high values for α and β. This can be done by setting m_1 to 10,000 and b_1 to 0.

It should be noted that because of within-seedbed variability, PC-SEED will predict different stocking values for seedbed area combinations that are seemingly equivalent. For example, different stocking will result from the following combinations:

(i) 1 seedbed, average receptivity 20%, seedbed area 30%

(ii) 2 seedbeds, average receptivity 20%, each with seedbed area of 15%.

Stocking in (ii) will be greater than in (i) because receptivities of the seedbeds in (ii) vary independently of each other. Because of this effect, users of PC-SEED should avoid "lumping" dissimilar seedbeds together, particularly if substantial areas are involved.

Summarizing seedbed areas

A frequency distribution of quadrat areas for a seedbed type can be displayed by selecting **|Graph|Frequency**. The seedbed type is selected by moving the cursor to the row with the desired seedbed type.

Generating seedbed areas

In the default mode ("Average" indicator appears in the upper right hand corner of the screen), seedbed areas are entered for each quadrat under the appropriate Q column. The average area for each seedbed appears under the Average column. It is not possible to enter values into the Average column when in the "Average" mode.

PC-SEED can also generate seedbed areas for individual quadrats. This is useful when seedbed area data for individual quadrats is not available, but the user does have an estimate of the average area of seedbeds. Select **|Calculate|Areas|Generate** to generate seedbed areas about the average value that appears under the Average column. Any subsequent entry under the Average column initiates generation of seedbed areas. In this mode, the "Generate" indicator appears in the upper right hand corner of the screen. It is not possible to enter individual quadrat values of seedbed area when in the "Generate" mode.

The number of quadrats for which seedbed areas are generated can be chosen by selecting **|Calculate| Areas|Generate|Quadrats**. The default number is 20, and values between 1 and 200 are permissible. Stocking estimates will be biased upwards if too few quadrats are used, particularly if the average seedbed area is low, or if the variance factor for seedbed area is high. For most circumstances, bias will be minimal if the number of quadrats is set to at least 100.

It is possible to specify the variance to be used in generating seedbed areas by selecting **|Calculate| Areas|Generate|Variance**. Entering a value for the variance factor causes areas to be generated with the following variance:

variance = factor x mean area x (100 - mean area)

Note that *mean area x (100 - mean area)* is the maximum variance that can occur for a given mean area. When a low factor is entered, the area of a seedbed type is similar among all quadrats (low variance). With a high factor, areas are highly dispersed (high variance). Maximum variance occurs when all seedbed areas are either 0 or 100%, and this condition is approximated by setting the factor to 0.99. The default value for the variance factor is 0.2, and the permissible range is from 0.01 to 0.99. A variance factor of 0.19 has been observed on shear-bladed peatland sites in northeastern Ontario (unpublished data), but it seems likely that lower variance factors occur on upland sites with a uniform site preparation pattern.

The **|Calculate|Areas|Generate|Variance** option generates seedbed areas according to the beta density function (see Appendix 5).

Generating seedbed areas is a numerically intensive procedure (see Appendix 5) and can be very time-consuming. In the worst case, with 20 seedbeds and 200 quadrats and a slow processor, many minutes may be required. The time taken increases linearly with the number of seedbeds and increases roughly with the square of the number of quadrats.

Note that each time a value is entered under the Average column, seedbed area generation is reinitiated. If the objective is to generate areas for a large number of quadrats for many seedbeds, it is possible to save a considerable amount of time by using one of two strategies. For the first strategy begin by selecting **|File|New** to erase the worksheet (also sets mode to "Average"). Then enter the mean seedbed areas for each seedbed type in the Q1 column. The same value will appear under the Average column. When all values have been entered, select "Generate" mode (**|Calculate| Area|Generate**) and seedbed areas will be generated for all quadrats and seedbed types. Alternatively, set the number of quadrats to 1 while in "Generate" mode. Then

enter the average seedbed areas in the Average column. When all areas have been entered, set the number of quadrats to the value desired.

Examining density relationships in broadcast seeding

Density can be examined by selecting **|Graph|Density** and the desired seeding rate scale. Density is simply a linear function of the seeding rate.

Examining seedspot relationships

Another important function of PC-SEED is to explore results when seeds are sown in spots. Seedspot stocking (percentage of spots with at least one seedling) values are displayed for all seedbed types by selecting **|Calculate|Seedspot|Go**.

More detailed seedspot results are displayed by selecting **|Graph|Seedspot**. A graph is displayed for the seedbed type that is currently active (cursor is on the row containing the seedbed name). The graph indicates the percentage of spots with 0, 1, 2, etc. seedlings, and also gives the average number of seedlings per spot.

Seedspot stocking and density are affected by the number of seeds per spot and the viability of the seed. The number of seeds per spot can be altered by selecting **|Graph|Seedspot|Seeds per spot**. The default is 5, and the permissible range is from 1 to 50. Note that number of seeds per spot refers to the total (viable and nonviable) number of seeds. The viability can be altered by selecting **|Graph|Seedspot|Viability**. The default viability is 100% and viability can range from 0 to 100%.

Within-seedbed variability affects seedspot stocking results just as it does stocking in broadcast seeding. See the section ***Within-seedbed variability (α and β values)*** on page 3 for more information.

Printing reports and graphs

PC-SEED can print two reports (select **|Graph|Print** and the desired report). The worksheet report prints all of the information contained in the worksheet (Figure 2), and the seedbed report summarizes information for each seedbed (Figure 3).

Graphs of stocking and density versus seeding rate (Figures 4 and 5), of seedspot stocking (Figure 6) and of seedbed area distribution (Figure 7) can be printed by selecting **|Graph|Print|Graph**.

Because graphs are printed using the DOS PrtSc service, the DOS **Graphics** command must be used in the PCSEED batch file or prior to executing SEED.EXE (see **Installing and Running PC-SEED**, page 1). The graph image remains on the screen until all of the graph information has been sent to the printer. This can take some time, and in the meanwhile, no keystrokes are accepted.

Applying PC-SEED

Applying PC-SEED requires information about seedbed amounts, seedbed receptivities, seeding rates, and seed viability. PC-SEED can operate with "best guesses", but more detailed information will likely result in prescriptions with greater reliability. Such information could include seedbed amounts from seedbed surveys, and seedbed receptivities from locally established seedspots.

Seedbeds that cover large areas may make a substantial contribution to stocking and density, even if receptivity values are low. These seedbeds should be included when developing prescriptions with PC-SEED.

Natural seed inputs from adjacent standing timber or from cones in slash can be considerable. An estimate of the natural seed input should be included in the applied seeding rate specified in **|Calculate|Broadcast|Seeding Rate**.

As a result of variations in site conditions or site preparation effectiveness, the amount, type and receptivity of seedbeds within a seeding block may vary. If sub-blocks can be identified, PC-SEED can be used separately on each sub-block to examine whether a single seeding prescription is suitable for the entire block.

If information on year-to-year or site-to-site variability in receptivity values is available, PC-SEED can be used to provide estimates of lower confidence limits for stocking or density. This can be done by entering a lower confidence limit for the receptivity value instead of mean value.

PC-SEED worksheet report: Peatland black spruce
Printed on 04-13-1999 Filename: SAMPLE.PCS

Seedbed Type	Recept	Area	Q1	Q2	Q3	Q4	Q5	Q6	Q7
compact Sphagnum	7.7	10.0	15.9	4.9	3.2	1.2	10.7	1.5	13.0
Sphagnum peat	33.4	7.2	2.2	13.8	8.5	1.1	10.8	2.7	6.7
Sphagnum and grass	6.9	3.5	2.7	1.1	2.0	1.3	1.0	1.0	21.7
pioneer mosses	11.4	3.2	4.7	3.2	1.7	1.4	0.9	0.9	1.0
feathermoss peat	3.4	3.8	1.8	2.3	3.1	1.1	1.0	1.0	13.8
displaced Sphagnum	20.6	2.3	0.9	1.8	15.6	0.9	2.7	0.9	0.9
deciduous litter	0.1	1.5	0.7	0.8	0.9	2.1	0.7	0.7	0.7
coniferous litter	6.4	1.7	0.8	0.9	11.8	5.1	0.8	0.8	1.5
sheared Sphagnum	42.7	1.4	1.8	0.8	0.7	0.8	0.7	0.7	0.7
displaced feathermos	3.4	1.1	0.7	2.4	0.6	0.6	0.6	0.7	0.6
rotten wood A	32.4	1.0	0.6	2.0	0.7	0.6	0.6	0.6	1.0
other	2.0	16.8	13.3	1.4	9.7	15.4	31.1	4.4	3.5
Quadrat Area:		53.5	46.0	35.5	58.6	31.5	61.7	15.9	65.1
Quadrat Stocking:		71.6	72.1	85.3	88.0	51.2	81.5	53.2	80.8

Seedbed Type	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
compact Sphagnum	30.4	6.0	1.8	2.6	24.0	1.2	1.3	8.8	2.1
Sphagnum peat	1.2	1.1	5.3	1.4	23.9	1.1	1.8	3.4	4.2
Sphagnum and grass	1.0	1.0	8.1	1.1	1.0	1.0	1.6	1.0	1.0
pioneer mosses	0.9	0.9	1.1	1.2	0.9	1.0	20.3	0.9	0.9
feathermoss peat	9.0	1.1	4.3	1.0	23.0	1.0	6.1	1.0	1.0
displaced Sphagnum	0.9	1.1	0.9	1.3	0.9	0.9	0.9	0.9	0.9
deciduous litter	0.7	0.7	0.7	0.7	0.7	0.7	1.2	0.7	0.7
coniferous litter	0.8	0.8	0.8	0.8	0.8	0.8	2.6	0.8	0.8
sheared Sphagnum	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
displaced feathermos	7.2	0.6	0.6	0.8	0.6	0.7	0.6	0.6	0.6
rotten wood A	0.6	6.3	0.6	0.6	0.6	0.6	0.6	0.6	0.6
other	36.2	6.8	17.8	26.9	1.9	42.9	11.4	53.0	8.2
Quadrat Area:	89.7	27.1	42.7	39.1	79.1	52.6	49.2	72.5	21.8
Quadrat Stocking:	65.4	70.9	70.0	52.1	88.6	47.6	68.4	64.4	60.7

Seedbed Type	Q17	Q18	Q19	Q20
compact Sphagnum	3.9	7.3	19.4	40.7
Sphagnum peat	34.1	17.9	1.2	1.6
Sphagnum and grass	3.7	12.7	1.0	5.4
pioneer mosses	11.5	7.2	0.9	2.3
feathermoss peat	1.0	1.0	1.4	1.2
displaced Sphagnum	4.4	1.0	0.9	7.8
deciduous litter	0.8	10.4	4.2	0.7
coniferous litter	1.1	0.8	0.8	0.8
sheared Sphagnum	1.1	9.6	0.7	3.8
displaced feathermos	0.6	1.2	0.6	0.6
rotten wood A	0.6	0.6	0.6	0.6
other	20.4	5.6	23.4	2.6
Quadrat Area:	83.3	75.1	55.3	68.2
Quadrat Stocking:	93.6	95.6	58.5	85.0

Figure 2. Worksheet report.

Figure 3. Seedbed report.

SEEDBED REPORT:
Peatland black spruce

Report Date: 04-13-1999

File: SAMPLE.PCS

	Seedbed Type	Receptivity (%)	Seedspot Stocking (%)	Average Area (%)	Alpha	Beta
1	compact Sphagnum	7.7	24.5	10.0	0.1440	1.7260
2	Sphagnum peat	33.4	73.5	7.2	0.6246	1.2454
3	Sphagnum and grass	6.9	22.2	3.5	0.1290	1.7410
4	pioneer mosses	11.4	34.3	3.2	0.2132	1.6568
5	feathermoss peat	3.4	11.5	3.8	0.0636	1.8064
6	displaced Sphagnum	20.6	54.3	2.3	0.3852	1.4848
7	deciduous litter	0.1	0.4	1.5	0.0019	1.8681
8	coniferous litter	6.4	20.7	1.7	0.1197	1.7503
9	sheared Sphagnum	42.7	82.9	1.4	0.7985	1.0715
10	displaced feathermos	3.4	11.5	1.1	0.0636	1.8064
11	rotten wood A	32.4	72.3	1.0	0.6059	1.2641
12	other	2.0	6.9	16.8	0.0374	1.8326

* Seedspot stocking values based on 8 seeds per spot with a viability of 100 %

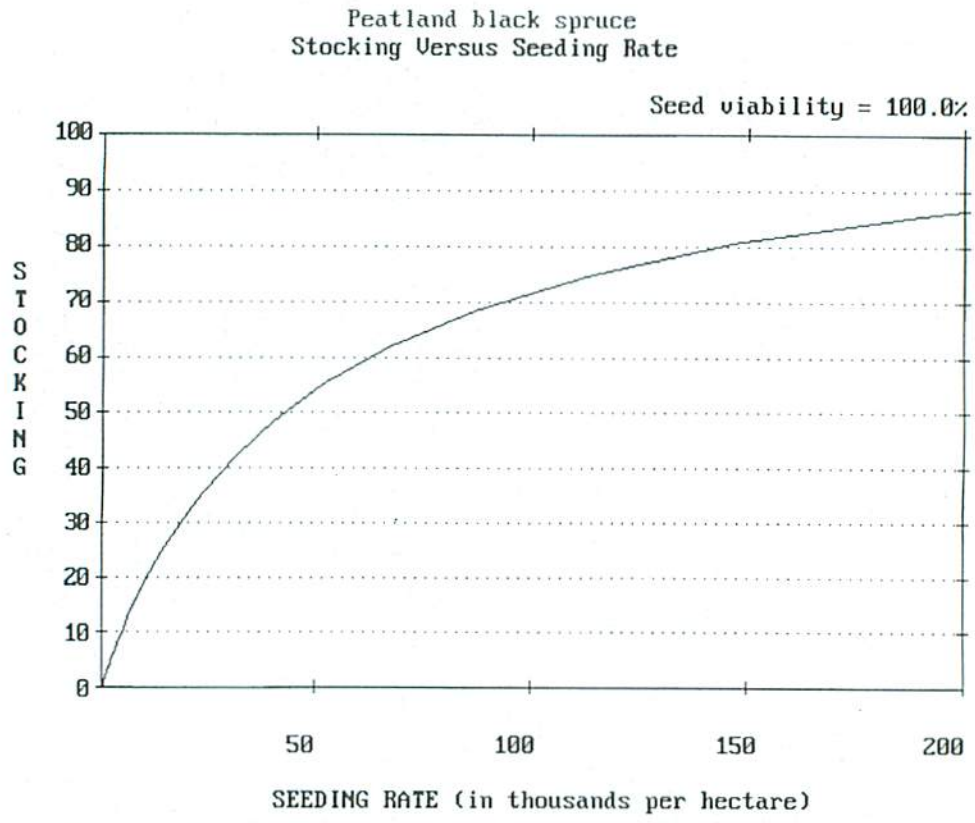

Figure 4. Stocking graph - broadcast seeding.

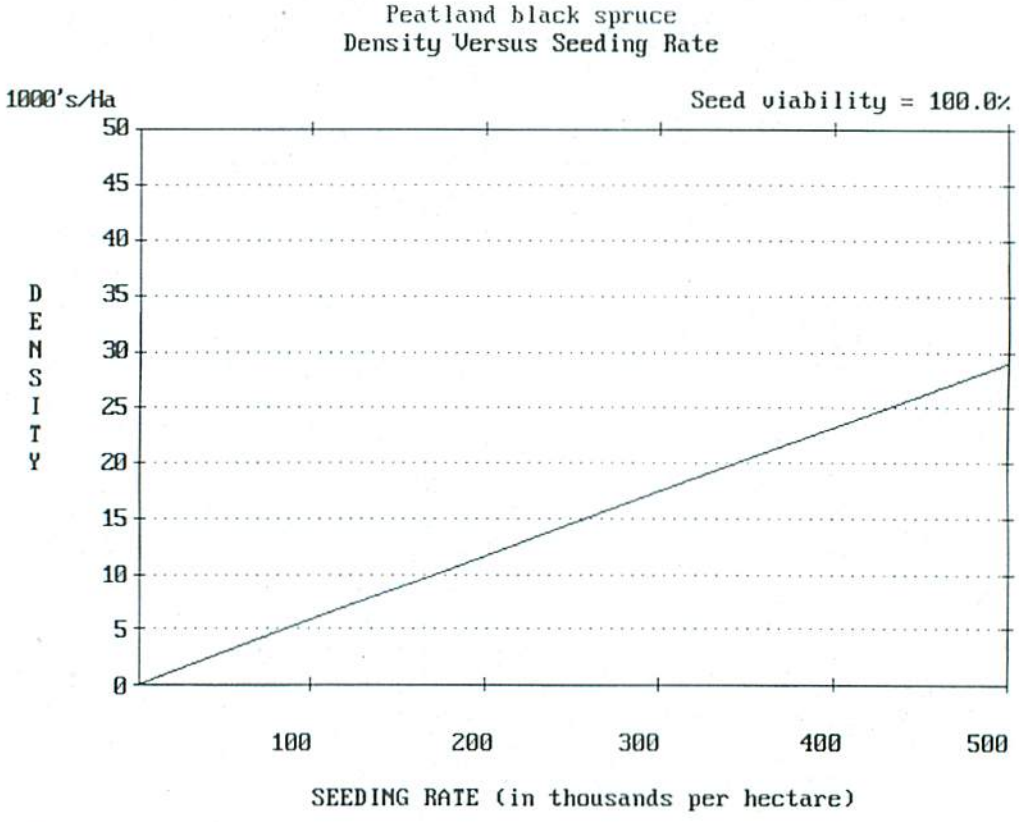

Figure 5. Density graph - broadcast seeding.

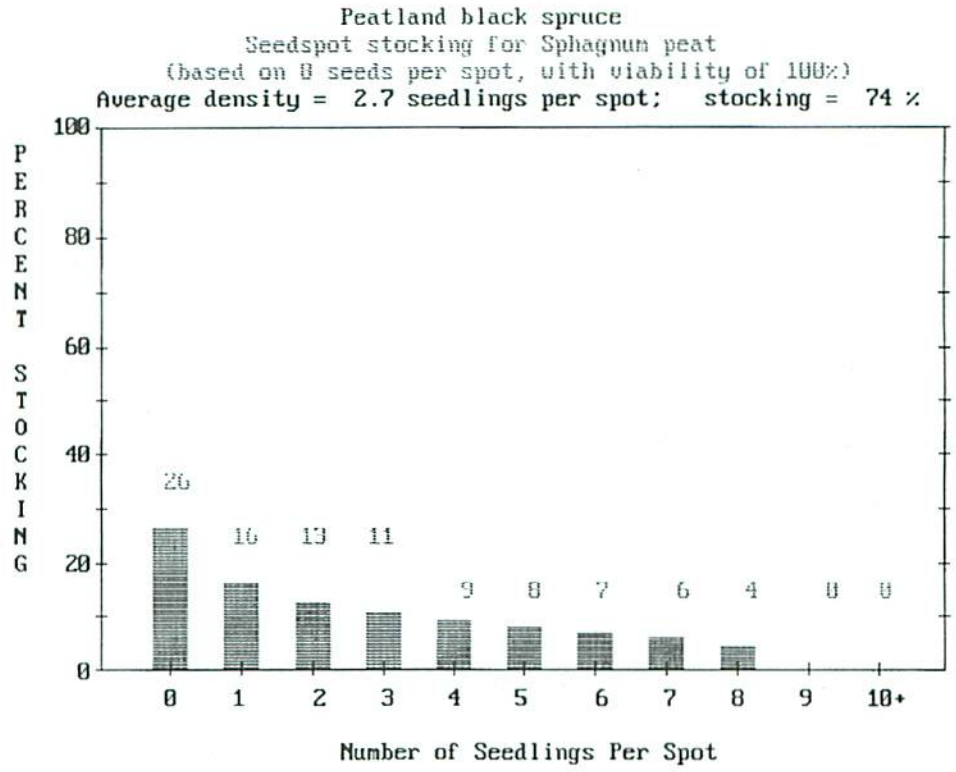

Figure 6. Seedspot graph.

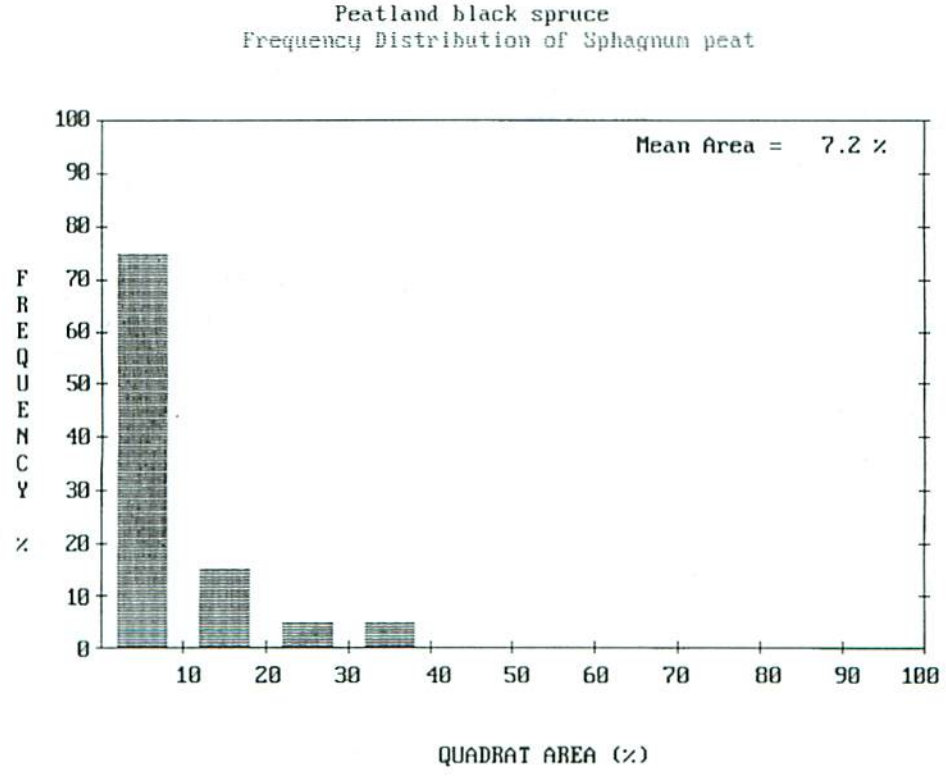

Figure 7. Seedbed area frequency distribution graph.

MENU COMMANDS

This section provides details on all possible menu commands.

|File

Carry out file operations including starting a new worksheet, retrieving a file, saving a file, shelling to DOS and setting a default directory, and exiting.

|File|New

Erase the current contents of the worksheet, and assign default values to all settings.

|File|Retrieve

Retrieve a PC-SEED data file. Only files with a **pcs** extension can be retrieved. The names of all files in the current subdirectory with this extension are displayed. Although PC-SEED saves ***.pcs** files in a standard format, some flexibility is possible in the format of files to be **Retrieved** (Appendix 1). Once a file has been **Retrieved**, the file name is displayed in the upper right-hand corner of the screen.

|File|Save

Save a PC-SEED worksheet to the current directory with the filename that is displayed in the upper right-hand corner of the screen. If the file already exists, its contents will be written over.

The files are written in text (ASCII) form with a standard format (Appendix 1).

|File|Save As

Save a PC-SEED worksheet to the current directory with a filename supplied by the user. If the file already exists, its contents will be written over. Files are always saved with a **pcs** extension, even if a different extension was entered.

The files are written in text (ASCII) form with a standard format (Appendix 1).

|File|DOS Shell

Shell to DOS. After the desired DOS commands have been executed, type **Exit** to return to PC- SEED.

|File|Directory

Change the current directory.

|File|Exit

Exit PC-SEED and return to DOS.

|Calculate

Set options for seedspot, broadcast seeding and quadrat area calculations.

|Calculate|Seedspot

Set options for seedspot calculations.

|Calculate|Seedspot|Seeds per spot

Set the total number of seeds per spot (viable + nonviable) for seedspot calculations (maximum number is 50). Default is 5.

|Calculate|Seedspot|Viability

Enter the seed viability expressed as a percentage (values from 0 to 100 are accepted). Default is 100.

|Calculate|Seedspot|Go

Determine seedspot stocking (percentage of seedspots stocked with at least one seedling) for each seedbed and display the results on the worksheet. Details of the seedspot stocking calculation are provided in Appendix 4.

|Calculate|Broadcast

Set options for broadcast seeding calculations.

|Calculate|Broadcast|Seeding Rate

Enter the broadcast seeding rate in thousands of viable seeds per hectare. The default rate is 100,000 seeds per ha; values from 0 to 500,000 seeds per ha are permitted.

|Calculate|Broadcast|Quadrat Size

Enter the size of the quadrat on which stocking calculation will be based. The default size is 4 m^2 and values from 0 to 100 m^2 are permitted.

|Calculate|Beta

Set values or parameters to estimate the values of the beta probability density function. The beta function is used to describe the degree of within-seedbed variability in receptivity (Groot 1988).

IMPORTANT NOTE: This is an advanced option that should be used only on the basis of detailed knowledge of seedbed receptivity. A method for estimating α and β values from seedspot information is provided in Appendix 2.

|Calculate|Beta|Enter values

Enter α and β values of the beta probability density function. Note that

$$r = \frac{\alpha}{\alpha+\beta}$$

where r = *receptivity/100*

Changing the values of α and β changes the receptivity value.

For a given receptivity, smaller values of α and β produce greater within-seedbed variability, and ultimately, lower stocking values.

The acceptable ranges of values are: $0 \leq \alpha < 10{,}000$ and $0 < \beta < 10{,}000$.

|Calculate|Beta|Parameters

Enter m_1 and b_1 parameters for the following equations to estimate values of α and β from r:

$$\alpha = m_1 + b_1 r$$

$$\beta = \alpha\frac{(1-r)}{r}$$

where r = receptivity/100

If a combination of r, m_1, and b_1 would result in $\alpha < 0$, the default values of b_1 and m_1 are used instead. Default values are $b_1 = 0$ and $m_1 = 1.87$, from Groot (1988).

Changing the values of receptivity at any time will produce new values of α and β based on these equations.

|Calculate|Areas

PC-SEED can be operated in two area modes. If you wish to enter the area of seedbed for individual quadrats, the **Average** mode is appropriate. With the **Average** mode selected, the average of the quadrat areas for each seedbed is updated whenever a new quadrat area is entered. Values cannot be entered into the Area column when in **Average** mode.

If you have only an estimate of the average area of seedbeds, and wish to generate individual quadrat areas for more realistic stocking predictions, the **Generate** mode is appropriate. When a value is entered into the Area column, values of area are generated for each quadrat. Values cannot be entered into any of the Q1...Qn columns when in **Generate** mode.

The word "Average" or "Generate" is displayed in the upper right hand corner of the screen to indicate which mode is operating.

|Calculate|Areas|Average

Select **Average** mode. Areas entered into columns Q1...Qn will be averaged in the "Area" column.

|Calculate|Generate

Select **Generate** mode. Areas entered into column "Area" will generate areas in columns Q1...Qn.

|Calculate|Generate|Variance

Enter a variance factor to control the dispersion of generated seedbed areas about the mean area. Seedbed areas are generated with the following variance:

variance = factor x mean area x (100 - mean area)

The variance factor is the desired variance divided by the maximum possible variance. Note that *mean area x (100 - mean area)* is the maximum variance that can occur for a given mean area. When a low factor is entered, the area of a seedbed type is similar among all quadrats (low variance). With a high factor, areas are highly dispersed (high variance). Maximum variance occurs when all quadrat seedbed areas are either 0 or 100%, and this condition is approximated by setting the variance factor to 0.99. The default value for the variance factor is 0.2; the permissible range is from 0.01 to 0.99. A variance factor of 0.19 has been observed on shear-bladed peatland sites in northeastern Ontario (unpublished data), but it seems likely that lower variance factors occur on upland sites with a uniform site preparation pattern.

|Calculate|Generate|Quadrats

Enter the number of quadrats for which seedbed areas are to be generated. The default value is 20, and values from 1 to 200 are permitted. Stocking estimates will be biased upwards if too few quadrats are used, particularly if the average seedbed area is low, or if the variance factor for seedbed area is high. For most circumstances, bias will be minimal if the number of quadrats is set to at least 100.

|Print

Print one of several outputs.

|Print|Graph

Print one of several graphs. Note that graphs can also be printed when they have been displayed using the **Graph** command by pressing "P".

Because graphs are printed using the DOS PrtSc service, the DOS **Graphics** command must be used in the PC-SEED batch file or prior to executing SEED.EXE (see **Installing and Running PC- SEED**, page 1). The graph

image remains on the screen until all of the graph information has been sent to the printer. This can take some time, and in the meanwhile no keystrokes are accepted.

|Print|Graph|Stocking

Print a graph of stocking versus seeding rate in broadcast seeding (see Figure 4).

|Print|Graph|Stocking|1) Scale 50

Select a seeding rate scale going from 0 to 50,000 seeds per ha for the stocking graph.

|Print|Graph|Stocking|1) Scale 200

Select a seeding rate scale going from 0 to 200,000 seeds per ha for the stocking graph.

|Print|Graph|Stocking|1) Scale 500

Select a seeding rate scale going from 0 to 500,000 seeds per ha for the stocking graph.

|Print|Graph|Density

Display a graph of density versus seeding rate in broadcast seeding (see Figure 5).

|Print|Graph|Density|1) Scale 50

Select a seeding rate scale going from 0 to 50,000 seeds per ha for the density graph.

|Print|Graph|Density|1) Scale 200

Select a seeding rate scale going from 0 to 200,000 seeds per ha for the density graph.

|Print|Graph|Density|1) Scale 500

Select a seeding rate scale going from 0 to 500,000 seeds per ha for the density graph.

|Print|Graph|Seedspot

Print a graph showing the percentage of seedspots with 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 or more seedlings per spot (see Figure 6) for the current seedbed.

|Print|Graph|Frequency

Print a graph of the relative frequency distribution of seedbed area for the current seedbed.

|Print|Worksheet

Print the contents of the worksheet (see Figure 2). The worksheet report reproduces the information contained in the worksheet including the name, receptivity and average area of each seedbed type; the area of each seedbed type in each quadrat; the mean total seedbed area and the mean stocking; and the total seedbed area and the probability of stocking for each quadrat.

|Print|Worksheet|Normal

Print the worksheet in normal text mode, 80 columns wide.

|Print|Worksheet|Compressed

Print the worksheet in compressed text mode, 137 columns wide. This option is possible for printers using the Epson command set.

|Print|Title

Enter a title (up to 40 characters) to be printed at the top of graphs or reports.

|Print|Seedbed Report

Print a report summarizing the receptivity, seedspot stocking, average area, and alpha and beta values for each seedbed type (see Figure 3). Seedspot stocking is the estimated stocking if seedspots were established on each seedbed type.

|Graph

Select one of several graph options.

|Graph|Stocking

Display a graph of stocking versus seeding rate in broadcast seeding (see Figure 4). Pressing "P" while the graph is displayed will print the graph; pressing any other key will return to the worksheet.

|Graph|Stocking|1) Scale 50

Select a seeding rate scale going from 0 to 50,000 seeds per ha for the stocking graph.

|Graph|Stocking|1) Scale 200

Select a seeding rate scale going from 0 to 200,000 seeds per ha for the stocking graph.

|Graph|Stocking|1) Scale 500

Select a seeding rate scale going from 0 to 500,000 seeds per ha for the stocking graph.

|Graph|Density

Display a graph of stocking versus seeding rate in broadcast seeding (see Figure 5). Pressing "P" while the graph is displayed will print the graph; pressing any other key will return to the worksheet.

|Graph|Density|1) Scale 50

Select a seeding rate scale going from 0 to 50,000 seeds per ha for the density graph.

|Graph|Density|1) Scale 200

Select a seeding rate scale going from 0 to 200,000 seeds per ha for the density graph.

|Graph|Density|1) Scale 500

Select a seeding rate scale going from 0 to 500,000 seeds per ha for the density graph.

|Graph|Seedspot

Display a graph showing the percentage of seedspots with 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 or more seedlings per spot (see Figure 6) for the current seedbed. Pressing "P" while the graph is displayed will print the graph; pressing any other key will return to the worksheet.

|Graph|Frequency

Display a graph of the relative frequency distribution of seedbed area for the current seedbed.

|Graph|Title

Enter a title (up to 40 characters) to be printed at the top of graphs or reports.

|Setup

Set screen mode or characteristics of the bottom line of display.

|Setup|Screen Mode

Change the screen mode. PC-SEED can be operated using either a colour or monochrome display.

|Setup|Screen Mode|Colour

Select a colour display. This is the default screen mode and is appropriate for colour monitors.

|Setup|Screen Mode|Monochrome

Select a monochrome display. This screen mode provides a clearer display when using monochrome monitors.

|Setup|Bottom Line

Change the bottom line of the display. Three options are available.

|Setup|Bottom Line|Stocking

Display stocking values for broadcast seeding along the bottom line. The stocking value under the Area column is the average stocking for all quadrats. The stocking value under the Qn column is the probability that the quadrat will be stocked. Stocking values are expressed as a percentage and are based on a quadrat size and broadcast seeding rate that can be set in **|Calculate|Broadcast**.

|Setup|Bottom Line|Area

Display area values along the bottom line. The area value under the Area column is the average of total seedbed area for all quadrats. The area value under the Qn column is the total area of all seedbeds for the quadrat n. Areas are expressed as a percentage of the quadrat area.

The default display for the bottom line is area.

|Setup|Bottom Line|Blank

Display nothing along the bottom line.

ACKNOWLEDGEMENTS

The substantial contributions made by Tom Alves in the programming of PC-SEED are gratefully acknowledged. Mike Adams, Rob Fleming and Colin Bowling provided constructive reviews of the software and the manual.

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Press, W.H.; Flannery, B.P.; Teukolsky, S.A.; Vetterling, W.T. 1986. Numerical recipes. Cambridge University Press, Cambridge. 818 p.

Régnière, J. 1982. A probabilistic model relating seeding rate and seedbed availability to degree of scarification and aerial seeding rate. Can. J. For. Res. **12:** 362-367.

Appendix 1. Format of *.pcs files.

PC-SEED writes ***.pcs** files in a standard format (e.g., Figure A1). Variables are written in the following order, one line for each seedbed type:

1 seedbed name (up to 20 characters)
2 α value
3 β value
4 receptivity value (%)
5 area of quadrat 1 (%)
6 area of quadrat 2 (%)

4+n area of quadrat n (%)

In the standard format, the seedbed name occupies 20 columns, and subsequent variables are separated by commas. Rather long lines may be created if there are many quadrats.

It is also possible to create ***.pcs** files using other software (word processors, editors, spreadsheets), however, and then to retrieve them using the **File|Retrieve** command. This would be useful for importing data that have been stored previously in other files.

Blanks are ignored by PC-SEED, so more blanks can be used than shown in the standard format, or no blanks can be used.

Values for variables can be omitted, but commas must still be entered to hold the variable's place. For example, the following line omits α and β values:

mineral soil, , , 32.1, 31, 25, 37

*Figure A1. Format of a sample **pcs** file.*

compact Sphagnum , .4675, 1.4025, 25, 1.169338, 1.421931, 3.815682, 42.82235, 1.678302, 32.4999, 3.091681, 12.19854, 4.689889, 5.733235, 6.969545, 8.42954, 10.15395, 2.035068, 14.64272, 17.60569, 21.27921, 26.00504, 2.502453, 1.255943

Sphagnum peat , .748, 1.122, 40, 1.13701, 2.648908, 1.229162, 2.169174, 1.534563, 4.975798, 1.348005, 1.163764, 21.94315, 17.47921, 4.027913, 1.803238, 7.558817, 9.296187, 11.43343, 14.0946, 6.138268, 3.261166, 28.23566, 38.52201

feathermoss peat , .0748, 1.7952, 4, 1.120672, 1.132554, 2.162268, 1.355336, 6.291801, 1.53827, 1.801324, 1.166813, 2.641242, 3.261722, 12.27205, 9.798359, 1.236457, 5.046894, 7.847229, 4.051919, 15.47202, 19.76184, 25.90796, 36.13327

rotten wood , .374, 1.496, 20, .6207932, .6207932, .6207932, .6207932, .6207932, .6207932, 6.337538, .6207932, .6207932, .6207933, .6207948, .6208071, .6208957, .6214468, .6244612, .6392145, .7048088, .9742139, 2.027886, .6207932

Appendix 2. Estimating α and β from seedspot information.

It is possible to estimate α and β values from seedspot data, and a program, BETA, is provided for this purpose. Estimates of α and β can be entered into PC-SEED to make more accurate stocking predictions.

Estimating α and β using BETA requires information on seedspot stocking (percentage of seedspots with one or more seedlings), receptivity value (percentage of seeds that become established seedlings), number of seeds per spot, and seed viability. At least 2 seeds per spot must have been used, and the same number must have been used for each spot. Seedbeds with low receptivity values require larger numbers of seedspots to accurately estimate α and β values.

Installing and running BETA is similar to installing and running PC-SEED. To use BETA, simply enter the seedspot information in the appropriate spaces, and then press F10 to calculate α and β.

Not all combinations of input data result in meaningful α and β values. BETA restricts inputs to the following conditions:

$$1 - (1 - v/100 \times r/100)^l > p/100 > r(1 - (1 - v/100)^l)/100,$$

where v is seed viability (%),
r is the receptivity value (%),
l is the number of seeds per spot, and
p is seedspot stocking (%).

The left-hand side of this inequality is the maximum seedspot stocking attainable, which occurs when there is no within-seedbed variability (see equation 1 in Groot (1988)). The right side of this equation is the minimum seedspot stocking attainable, which occurs when there is maximum within-seedbed variability (r percent of seedspots have 100% receptivity and the remainder 0% receptivity).

The basis for BETA is a numerical solution of the seedspot equation given in Appendix 4 for Pr(0), and Equation 1 in the text.

Appendix 3. Details of stocking calculation for broadcast seeding.

This calculation is based on Groot (1988). The probability of a quadrat being stocked is given by:

$$y = 1 - \left[\int_0^1 f(r_1)e^{-SA_1r_1}dr_1\right]\left[\int_0^1 f(r_2)e^{-SA_2}dr_2\right] \ldots \left[\int_0^1 f(r_n)e^{-SA_nr_n}dr_n\right]$$

where $f(r_n)$ is the probability density function for seedbed receptivity for seedbed n,
A_n is the area of seedbed n (m^2), and
S is the seeding rate (viable seeds m^{-2}).

The beta probability density function was used for $f(r_n)$. Numerical integration of this equation was simplified by the relation:

$$\int_0^1 f(r)e^{-SAr}dr = \sum_{m=0}^{\infty}\left[\frac{e^{-AS}(AS)^m}{m!}\frac{\Gamma(\alpha+\beta)\Gamma(\beta+m)}{\Gamma(\beta)\Gamma(\alpha+\beta+m)}\right]$$

The first term (m = 0) of the right-hand side of this equation reduces to:

$$e^{SA}$$

Succeeding terms (m = 1, 2, 3, ...) are evaluated by multiplying the previous term by:

$$\frac{AS}{m}\frac{\beta+m-1}{\alpha+\beta+m-1}$$

In PC-SEED, terms are evaluated until m > AS and the value of the term is < 1E-08.

When values of α and β are very high (i.e., small within-seedbed variability), the value of y approaches:

$$y = 1 - e^{[-S(\bar{r}_1A_1+\bar{r}_2A_2+\ldots+\bar{r}_nA_n]}$$

which is the equation originally developed by Régnière (1982) for predicting stocking without considering within-seedbed variability.

Appendix 4. Details of stocking calculations for seedspots.

The probability of a seedspot having k seedlings is given by:

$$Pr(k) = \sum_{i=k}^{l} \binom{l}{i} v^{i}(1-v)^{l-i} \binom{i}{k} \frac{\Gamma(\alpha+\beta)\Gamma(\alpha+k)\Gamma(\beta+i+k)}{\Gamma(\alpha)\Gamma(\beta)\Gamma(\alpha+\beta+i)}$$

where l is the total number of seeds (viable + nonviable), and
v is the seed viability.

This equation is taken from Groot (1988).

Appendix 5. Details of the method for generating quadrat areas.

It is assumed that quadrat areas are distributed according to the beta density function. The values of α and β are determined by the method of matching moments:

$$f = s^2/[(1\text{-}mean)mean]$$

$$\alpha = mean(1 - f)/f$$

$$\beta = (1 - mean)(1 - f)/f$$

where *mean* is the mean fractional area for the seedbed type, and s^2 is the variance of fractional area for the seedbed type.

The cumulative frequency distribution for the beta function is used as a basis for generating quadrat areas. With n quadrats for which to generate areas, areas corresponding with relative frequencies at intervals of 1/(n+1) beginning with 1/(n+1) are determined. Area values are determined using the Newton-Raphson procedure, and the cumulative frequency for an area value is determined using the BETAI algorithm (Press et al. 1986).

Quadrat areas generated at this stage usually have a mean slightly different from the desired mean, so rescaling is carried out to obtain the desired mean.

When areas are generated for more than one seedbed type, the fractional area for a quadrat may exceed one. An iterative procedure is used to exchange pairs of quadrat areas to minimize these occurrences. Exchanges of areas take place only between quadrats within the same seedbed type.

After this stage, total areas for some individual quadrats may still exceed one by a small amount. This is corrected by reducing the area of a seedbed in such a quadrat, and increasing the area of the same seedbed type in another quadrat by the same amount.

The final result is that all seedbed types have the desired mean area, the total area of each quadrat is less than or equal to one, and the areas of each seedbed type are, to a close approximation, beta-distributed.